An AI Based System for Objective Tropical Cyclone Intensity Estimation

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1 – NASA IMPACT, 2 – NASA Marshall Space Flight Center, 3 – Development Seed

Outline

- Motivation
- Introduction/Background
- Data/Methodology
- Model Evaluation
- Deploying model in production
- Challenges and Lessons Learned
- Conclusions/Future Work

Motivation

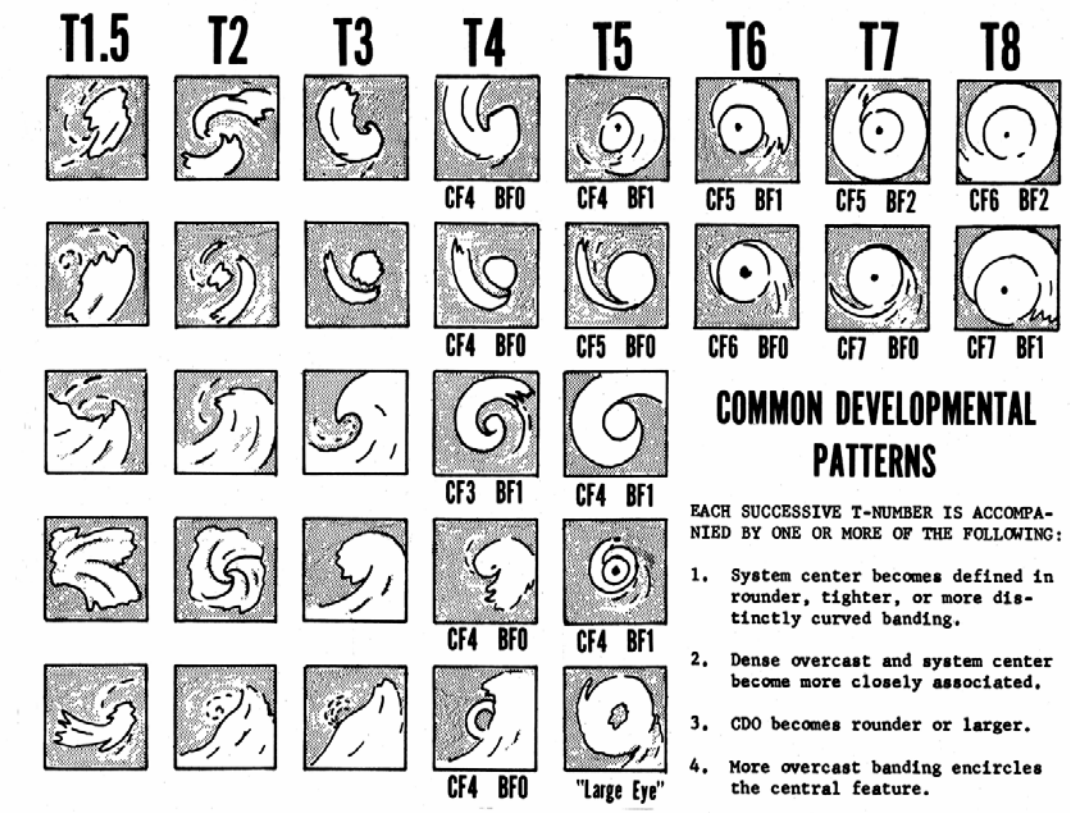
15 UTC 10 Oct 17 NHC advisory on Tropical Storm Ophelia:

*"Dvorak intensity estimates range from T2.3/**33 kt** from UW-CIMSS to T3.0/**45 kt** from TAFB to T4.0/**65 kt** from SAB. For now, the initial intensity will remain at **45 kt**, which is an average of the scatterometer winds and all of the other available intensity estimates."*

1. **Can we objectively estimate wind speed from satellite images?**
2. **Can we estimate more frequently?**

Intensity Estimation Current Approach

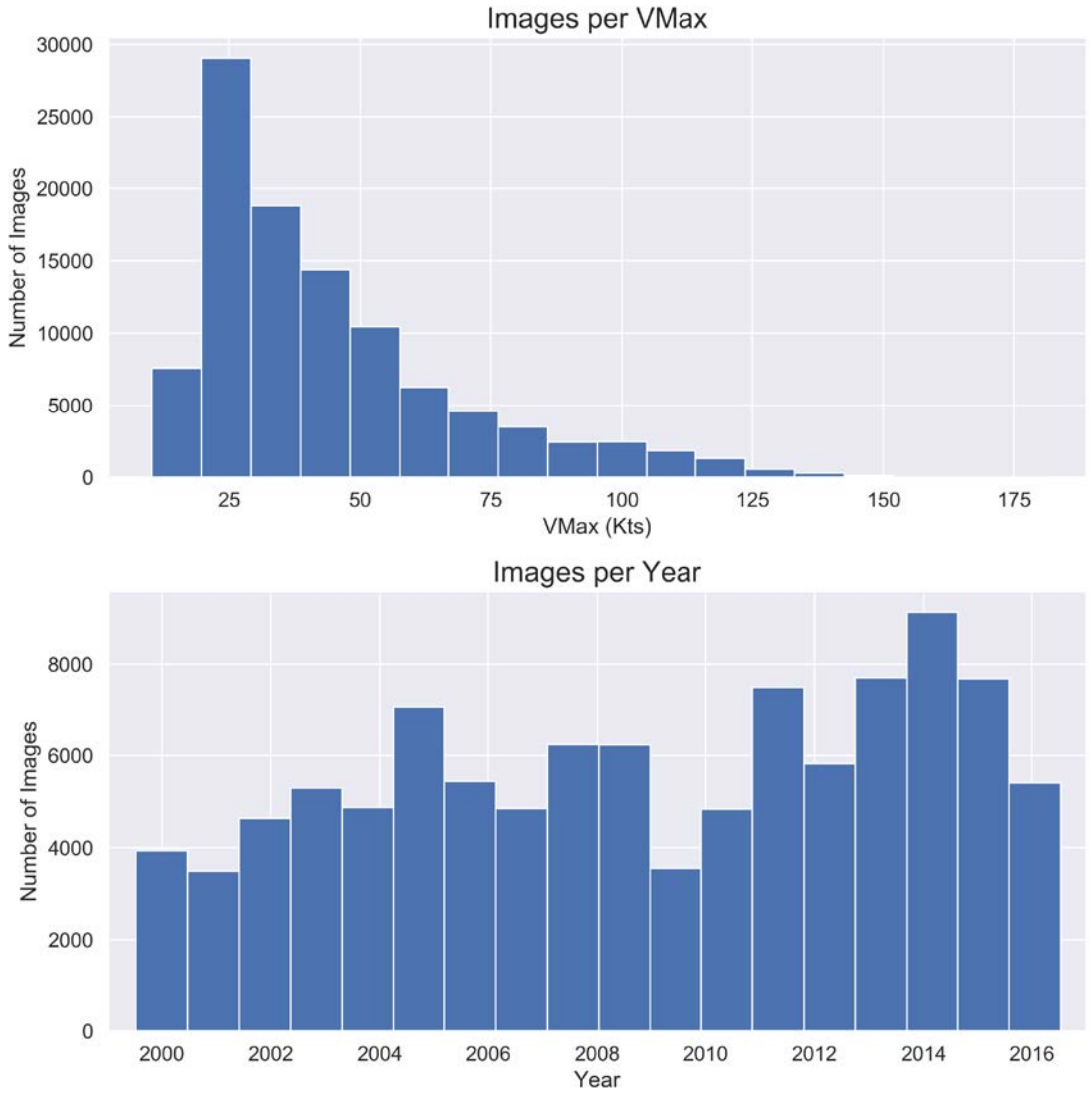
- The Dvorak technique
  - Vernon Dvorak (1970s)
  - Satellite-based method
  - Based on cloud presentation in IR images
  - A T-number is assigned based on the visual pattern of clouds



- Problems with current approach:
  - Subjective
  - Lack of generalizability
  - Inconsistency
  - Requires domain expertise

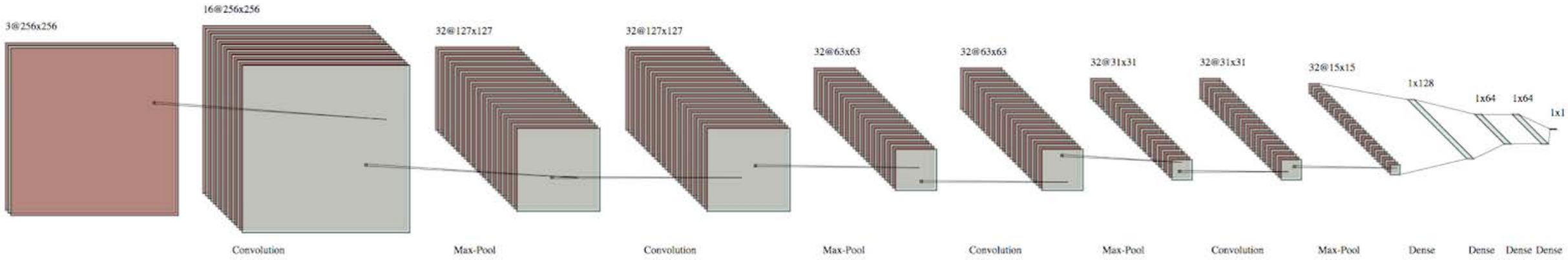
Data

- GOES IR imagery
  - Atlantic and Eastern Pacific Basins
    - 103,600 total images
      - 2000 - 2017
    - 2017 used for testing (5410)
    - GOES08 – GOES15
  - 5 degrees around center of storm
- Labeled with HURDAT2 reanalysis data



Methodology

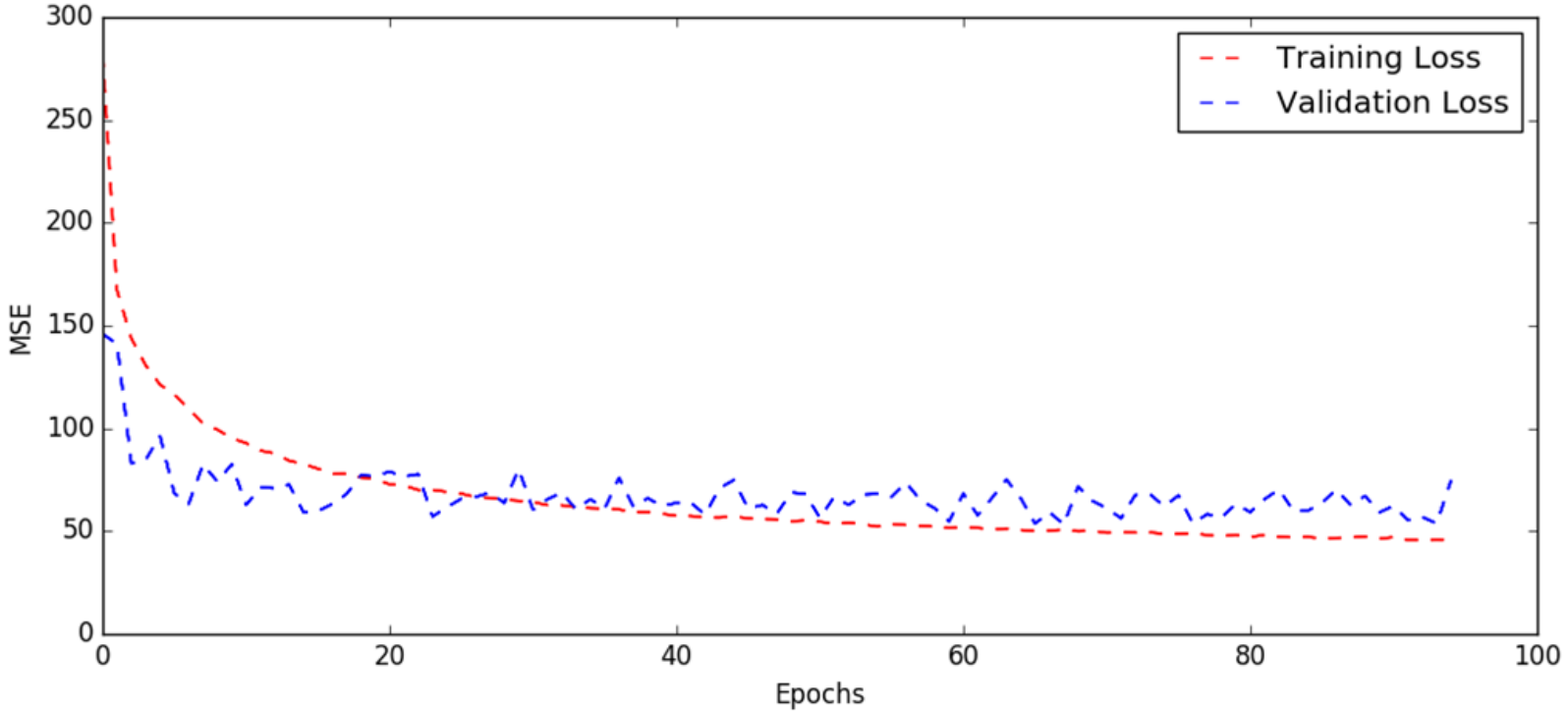
- Performance struggled when binning the wind speeds into discrete classes
- Used a custom network architecture that outputs an actual wind speed estimate rather than a class (linear model)
  - 4 convolutional layers
  - 4 dense layers
  - 1 output
- Model was built using TensorFlow



Model Evaluation

Test set (2017 storms):

- RMSE: 10.39 Kts
- MAE: 7.58 Kts



North Atlantic

Piñeros et al. (2011): 14.7*kt*

Ritchie et al. (2012): 12.9*kt*

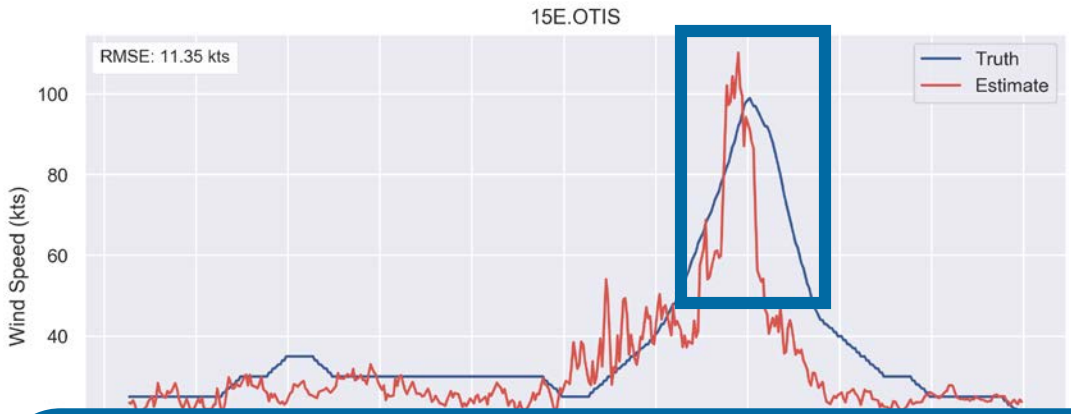
North Pacific

Ritchie et al. (2014): 14.3*kt*

Performance on individual storms

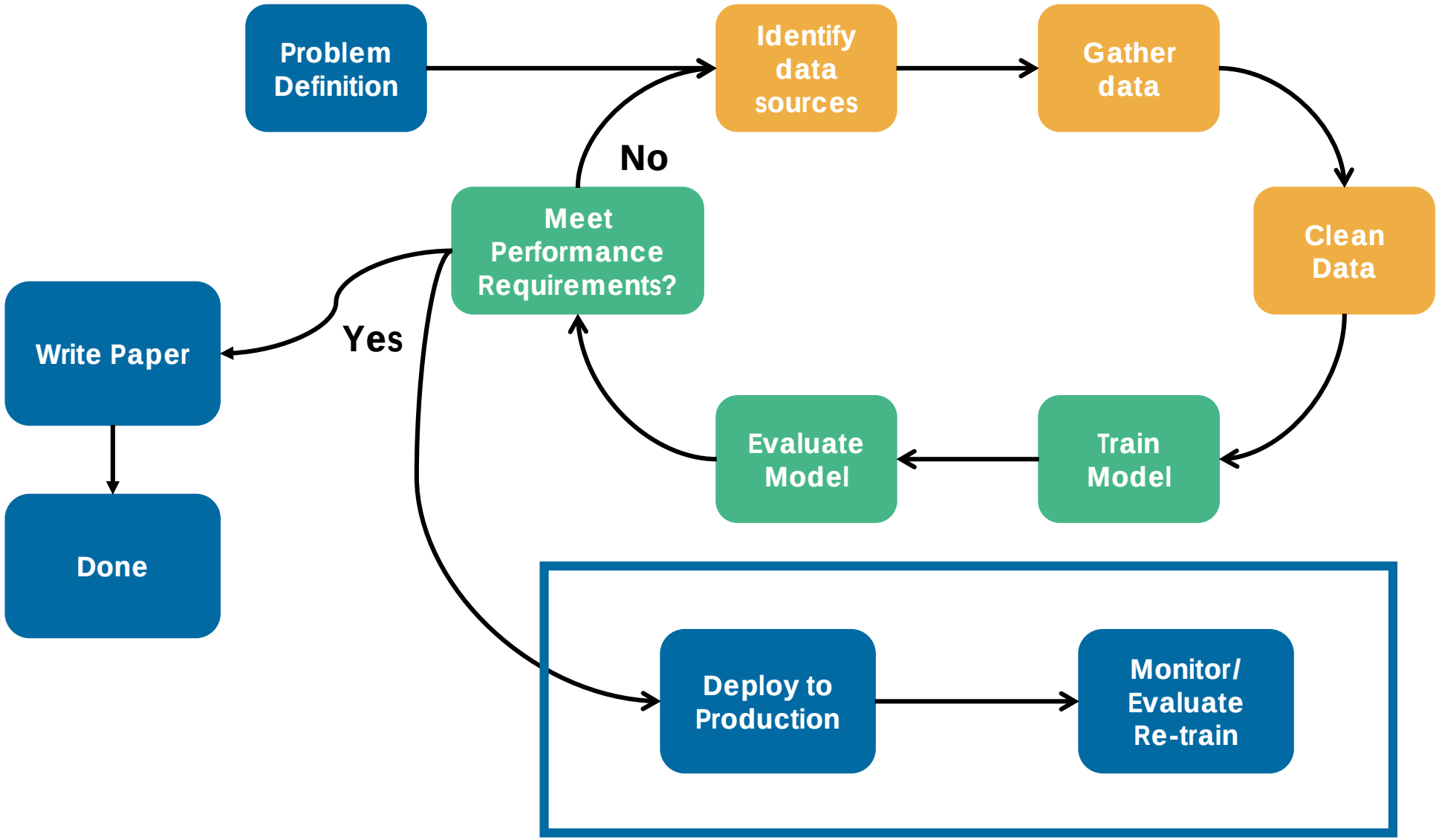
Atlantic:

East Pacific:



"The cloud pattern now only supports an intensity of about 45 kt, but **Dvorak intensity estimates are constrained to higher values by the rules of the technique**. Given the small size of Otis, it seems possible that this is a rare case where **the intensity is dropping faster than the Dvorak technique allows**."
- Tropical Storm Otis Discussion Number 28

Model Deployment



Coordinated Effort

ML Researchers

- Transform ideas into models
- Training data
- Monitor

End-user stakeholders

- Production Requirements

Marshall Space Flight Center

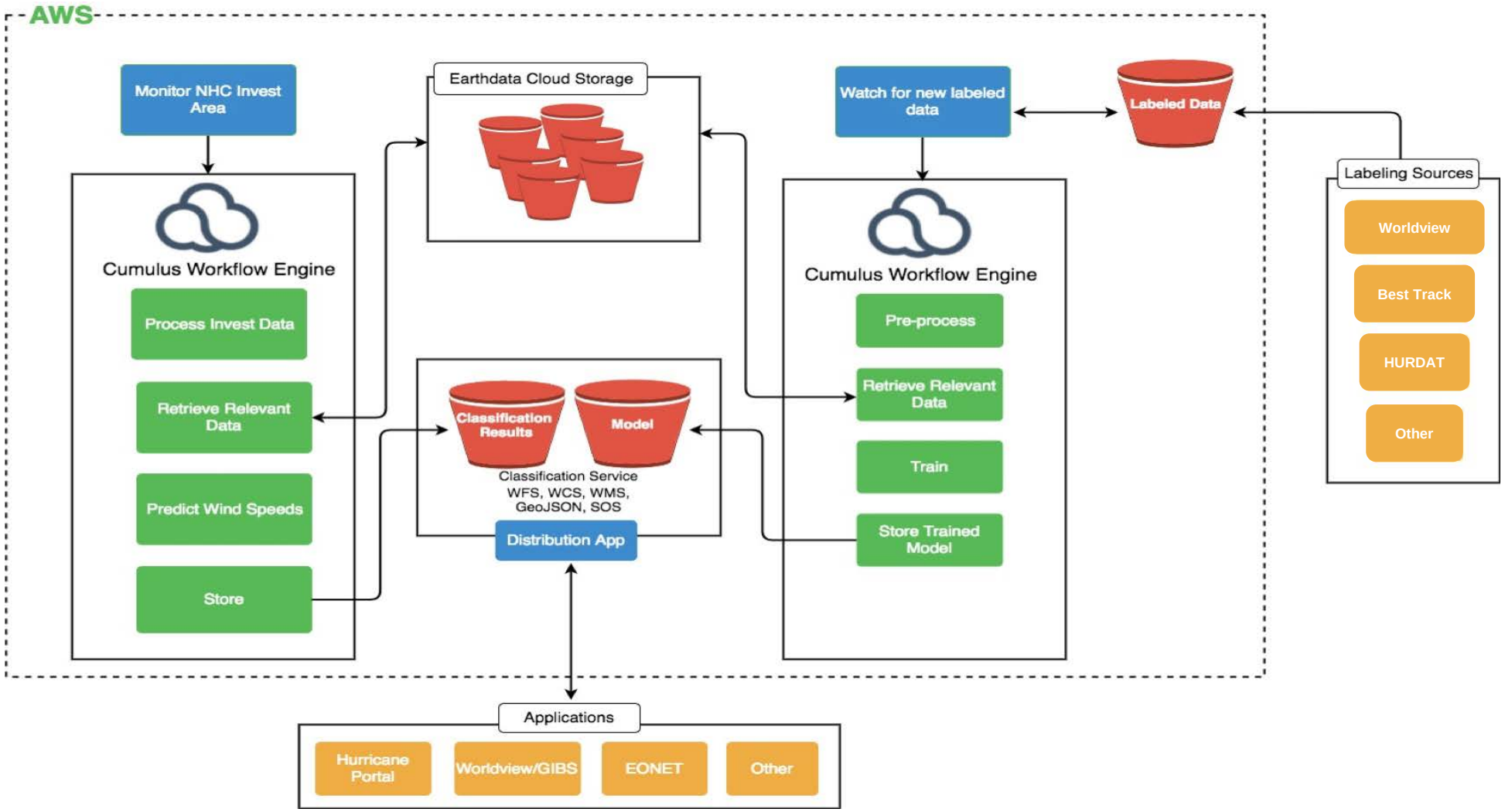
Domain experts

- Evaluation
- Performance baselines
- Science use case

ML/System developers

- Design
- Quick prototype
- Deploy to production
- Scale
- Log

Portal Workflows



Challenges and Lessons Learned

- Acquiring consistent large scale training data
  - NRL/CLASS
  - HURDAT/Aircraft recon
- Interpreting why a model is performing poorly
  - AI black box
- Properly versioning training data, models, and algorithms can be difficult
- Complexity with evolving platforms and infrastructure

Conclusions/Future Work

- We developed a deep learning model to objectively estimate hurricane wind speed
  - 10.39 kts RMSE
  - Works in both basins
- Deployed model in production environment
  - http://hurricane.dsig.net/
  - Utilizes *Cumulus* to execute workflows
- Other satellite imagery deep learning projects
  - Event detection
  - Phenomena detection
  - Smoke detection

Questions?

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http://hurricane.dsig.net

developmentSEED

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